Reducing the Landfilled Stream in Central Ohio

Thesis

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By

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Abstract

The purpose of this research is to assess what benefit a Mixed Waste Processing Facility (MWPF) could have in Columbus, Ohio; either replacing, or in addition to, the current single stream program. MWPFs may have the potential for higher rates of recovering recyclable materials, but it is significantly more costly than a single stream recycling facility. Columbus has a single stream recycling facility that captures recyclable materials segregated by residents, but the amount of recyclable material diverted from a landfill could be higher if the "participation rate" in theory rises to 100 percent if garbage is sorted at a MWPF. If the city of Columbus switches to a MWPF, then this may increase the total amount of recovered materials, reducing the cost associated with expanding landfills. However, it is not clear whether the benefit of increasing the amount of recycled material (thereby reducing the need to expand the landfill) justifies the cost of doing so, or if it is even possible through this method. This report includes an analysis of various recyclable materials and what facilities should focus on to be economical. With the current landscape, the best option for the city of Columbus is to have a single stream system combined with a mixed waste system, but the mixed waste process must focus primarily on organic materials for composting.

Vita

Personal Information

Scotts Miracle-Gro — Marysville, OH
Assistant Brand Management Intern — May 2018 – August 2018

- Developed creative and execution for a best-in-class in-store display for a new product launch
- Developed schedule for complimentary products to support the new product launch
- Conducted research to interpret industry trends, market demand, and seasonality
- Analyzed digital platforms and recommended value adding integrations for new website
- Effectively managed cross departmental and external support partners

National Beverage Corp. — Obetz, OH
Supply Chain Management Intern — May 2017 - November 2017

- Managed Inventory report for 12 warehouses
- Identified waste reduction opportunities that arose from rapid growth of LaCroix
- Managed project to create a scorecard for the supply chain department
- Constructed reports to: support collaboration between plants, optimize ordering and forecasting, and more effectively manage inventory

Sauder Woodworking Co. — Archbold, OH
Operations Management Intern — May 2016 - August 2016

- Improved accuracy of order runtime prediction by 10%
- Scheduled hardware department of over 25 people
- Developed criteria for multi-million-dollar machine purchase
- Identified costs of implementing solutions for a packaging complaint
- Forecasted sales and identified low performing products to be discontinued

Research Project Experience
Creating a proposal for SWACO and the City of Columbus to extend the life of the landfill

- Conducted market review of current technology and trends
- Identified current best-in-class strategies and opportunities for improvement
- Evaluated failed attempts to identify pitfalls
- Analyzed environmental impacts and value of post-consumer materials
- Built and managed relationships with external support partners to drive progress

Publications

N/A

Fields of Study

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Minor Field: Agribusiness and Applied Economic

Research in: Management Sciences/Operations Management

Awards

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Chapter 1. Introduction

Single stream and mixed stream recycling have different rates of recovering recyclable materials. Single stream programs recover over 95 percent of what comes into their facility, but that is 95 percent of the participation rate (ex. 50% of people recycle * 95% recovery = 47.5% recovered). According to a report by the Environmental Protection Agency, the national average recovery amount is 34.6 percent. Mixed stream recycling has the potential to capture recyclable materials at a higher rate, but the quality of the recovered materials is a concern. The key difference between a single stream and a mixed waste processing facility is where the recyclable materials are separated from the rest of the waste. In a single stream facility, residents are responsible for segregating recyclable materials from garbage that will go into a landfill. In contrast, recyclable material is separated from waste at a mixed waste processing facility (MWPF), eliminating the need for residents to separate them. However, MWPF is more expensive than a single stream facility, and have been shown to lead to higher consumption habits. Is the mixed stream approach better than single stream recycling?

The focus of this project is to explore the most beneficial recycling process for the city of Columbus, whether that be supplementing current efforts or starting from scratch. I decided to focus on Columbus because over 75 percent of the population in Central Ohio live in the city limits. The main factors that can influence the effectiveness of recycling systems are the state of the current technology, the level of consumer participation, the waste stream profile in the area, the willingness of the municipality to pay for recycling services, the age and condition of existing waste management infrastructure, the demand for recycled materials, and the cost of disposal (Flower, 2015). Due to some of these factors being highly variable by region there may not be a one-size-fits-all approach. For example, since Central Ohio already has a decent recycling program in place, my recommendation to them could be different than my recommendation for a city starting from scratch like Houston, that only has a 6 percent recycling rate (Quinn, 2016).

This research draws from the knowledge and insights from the top manufacturers in the industry, two industry specific consulting firms, and the experience of various successful and failed facilities across the country. The report summarizes estimated costs and benefits of mixed waste facilities from Machinex, Bulk Handling Systems (BHS), Van Dyk Recycling Solutions (VDRS), Stadler, CP Group, Gershman Brickner and Bratton Inc. (GBB), and Resource Recycling Systems (RRS). I also describe the failed agreement that Central Ohio had back in 2014 with a company called Team Gemini to build a Sustainable Business Park next to the landfill and the recent failed MWPF in Alabama.

I conducted analysis of various end products to know what the focus of a successful facility should be. Then I give cost estimations and recommendation for what Columbus could and should do moving forward. I find that investing in a MWPF that can recover all types of recyclable materials (metal, paper, glass, etc.) is not recommended due to the contamination causing low recovery. I do find that it is more feasible to invest in an MWPF for separating organic waste only (i.e., compostable materials). This is more economical because it is a larger portion of the stream keeping more landfill space open, there is no concern about contamination, and it still allows for the future hope of getting those other materials out on the back end.

It is also prudent to point out that current practices in some cities in California may not be viable in Ohio. One reason for this is that the potential political barriers to pass laws that will require residents to separate their trash into three separate bins may be difficult to overcome. My proposal will not require any changes in the law but will be an improvement over current practices and allow for that transition in the future with no capital waste. The next section is a brief overview of the evolution of the recycling processes and technologies in the past four decades.

Chapter 2. Overview of the Recycling Industry

Municipal Solid Waste (MSW) is garbage that goes to a landfill. The total amount of recovered recyclable materials have been increasing over the past few decades, while landfilled material has remained relatively steady since the late 1970's as shown in Figure 1 below (Gershman, 2015, p. 5). Figure 1 shows that the total amount of recycled materials remained roughly the same from 2005-2010. Yet, there are many opportunities to increase the rate of recovery for recyclable materials and to decrease the total amount of landfill waste.

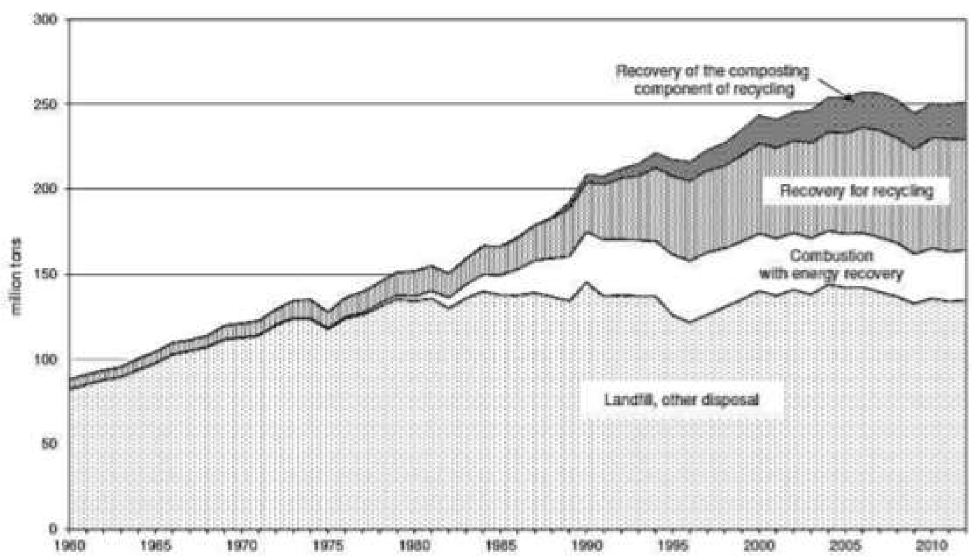

Figure 1: MSW Production and Management: 1960-2012

Material Recovery Facilities (MRFs) have been used since the 1970's, and this is where most recyclable materials are recovered. There are three popular types of MRFs:

(1) source separated, where everyone separates their own trash and puts it in separate bins or drop-off centers, (2) single stream system, where all recyclables are put in one bin and are taken to a machine that separates them further, (3) MWPF, originally called a dirty MRF because of the contamination, where a machine sorts through the entire dumpster to sort out the valuable materials so there is no separation at all required at the individual level. Single stream has made source separated obsolete because it is cleaner and more efficient. The purpose of this paper is to compare whether the higher cost associated with the MWPF justifies its potential benefits of increased recovery rates compared to the single stream system.

There are also different end products these facilities create. Some sort out the valuable raw materials for resale, some only create energy and are usually referred to as Waste to Energy (WTE) facilities, and others do both. Among WTE there are many different technologies with the most popular being mass burn, where everything is burned, resource derived fuel (RDF), which is usually a product of plastics, and Anaerobic Digestion (AD) that can be done for the organic portion of the waste stream. These are important to note because single stream and mixed waste can both do these, but it can skew the facts. For example, some mass burn facilities tout 100 percent recovery rates, like the entire country of Sweden, because it isn't sent to the landfill, but that is not true recovery. Creating energy from waste is much less sustainable then utilizing it for the raw material it is, which will be delved into more later.

Chapter 3. The Current State of Recycling in Columbus

Columbus has had a strong focus on recycling. Columbus currently has a single stream system managed by Rumpke. The average recycling rate is at about 42 percent, well above the national average of 34.6. The main landfill in the area is managed by the Solid Waste Authority of Central Ohio (SWACO). SWACO and the city of Columbus have tried to supplement their single stream efforts and decrease the amount of material being landfilled.

Back in 2013/2014 SWACO had a deal that failed with a company named Team Gemini. This deal was intended to help minimize the amount of trash landfilled. Team Gemini was going to create a sustainable business park that would bring in companies to sort and use the material before it was landfilled. The main reason given for this deal falling through was the inability of Team Gemini to find sufficient funding. This facility would not have affected Rumpke because it would have acted as a last resort sort. The material that it would receive would be from garbage bins that Rumpke does not take to its recycling facility. I feel that it is important to analyze this deal to know what would need to be changed for it to have been successful.

To start let's look at what one of the best consultants in the industry, GBB, says about Recovery Parks (also known as: Sustainable Business Parks or EcoParks). These parks create what is known as an Industrial Ecosystem or Industrial Symbiosis and are companies that are within close proximity to each other and collaborate to use the by-products from the other as inputs or shared resources whenever possible (Scozzafava, 2015). This is a very sustainable process but trying to do it all at once may be too capital intensive.

However, this symbiosis is a great long-term goal, especially in today's climate with the new National Sword regulations from China that have banned some of our recyclables and heightened the contamination requirements on others. These regulations have led to companies avoiding sending recyclables over due to getting rejected at customs and has flooded the local markets, driving prices down, and opening great opportunity for businesses to utilize them (Staub, 2018). Team Geminis plan would have been good at hedging against these new events.

The deal between Team Gemini and SWACO was complex and far from ideal. The mixed waste processing facility was to consist of a landfill receiving facility (LRF) and a Center for Resource Recovery and Recycling (COR3). The LRF was to be owned and operated by SWACO and the COR3 by Team Gemini with the buildings having a combined area of more than 185,000 square feet (Team Gemini, 2016). The receiving facility, that SWACO would own and operate was expected to cost roughly $18 million and be fully paid for by Team Gemini (Jarman, 2013). It appears the facility was planned to process 2,000 tons per day and eventually double to handle the entire waste stream in the future with only 1,000 of the 4,000 tons initially expected to be recovered. The annual rent payment for the 350 leased acres was $350,000 with a 99-year lease and the facility was projected to cost $100 million for the initial 25 percent recovery, rising to a potential

$300 million of private money and creating about 300 permanent jobs for 100 percent recovery (Jarman, 2013) (Team Gemini, 2016). Problems seem inevitable with each entity having a facility they are responsible for and the large upfront capital required to meet intended scale.

SWACO was excited about the potential of this project. According to Ron Mills the Executive Director of SWACO, the facility would recover metals and plastics, use organics for anaerobic digestion and have other sustainable energy generation technologies (Team Gemini, 2016). Garbage trucks would have taken trash there to separate recyclables that Team Gemini would have then sold. The residual material would then be taken to the landfill where they would pay a fee to dump the remainder (according to SWACO the Franklin County Sanitary Landfill charges $39.75 a ton in 2018 and in 2016 it was an even higher $42.75). According to the president of Team Gemini,

> They intended to operate 35 acres of state-of-the-art greenhouses on the property to grow organic crops to sell. The goal is to be completely self-contained, he said, so that all the energy used by the companies in the park, as well as the businesses' heating, cooling, water and waste-water needs, can be met onsite (Jarman, 2013, p. 17).

Team Gemini was planning on selling a lot of the recovered material to companies that would hopefully come in and set up shop next to the MWPF. SWACO and Team Gemini were on the same page and both excited, but this seems to have been merely a pipedream.

Team Gemini and SWACO made the following errors. They greatly underestimated the costs which rose to around $400 million (Ball, 2017). They also wanted to create space for other companies to come in at the beginning without having a plan in place for selling the materials to other parties until that happened. It is respectable that they wanted to create the best facility they could, but they needed to focus more on realistic cost estimates and having startup plans in place to offload material until companies came to set up shop. Finally, SWACO should have had a stronger focus on ensuring a mutually beneficial relationship because the graduated scale of costs for tonnages returned to SWACO seemed unmanageable. Recycling is no longer a profitable business (which will be covered in more detail in Chapter 5) and these types of relationships need to be set up for mutual success and assistance in times of hardship.

A big concern after a deal like this falling through and leaving SWACO with bills that were not fulfilled is that they are not immediately looking to find another solution to extending the life of their landfill. However, according to the director of SWACO, Ty Marsh, they are still very interested in pursuing waste minimizing deals. This is what Mr. Marsh said on the matter, “The failure of the Team Gemini project in no way diminishes our interest in leveraging the waste that’s generated in Franklin County for greater economic opportunity” (Rouan, 2016, p. 18). It is respectable and beneficial to the community that the authority still has sustainability as its number one priority.

Chapter 4. Learning from a failed recycling facility in Montgomery, Alabama

IREP is the most recent example of a MWPF failing, but instead of letting people use it to write MWPFs off as not viable it is crucial to figure out exactly what the problems were. IREP broke ground on July 13, 2013, opened on April 14, 2014, and shut down in October of 2015. IREP was a 30-tph, facility that signed a deal to receive a minimum of 100,000 tons per year from Montgomery, Alabama. There was minimal to no recycling efforts in Montgomery so IREP would receive a stream much higher in plastic, metals, and fibers then what would be expected from Columbus dumpsters. IREP seems to have been far too optimistic in its expectations for this endeavor.

The first problem was the expected recovery rates. The landfill divergence levels that IREP said they could achieve vary depending on the source, some have reported 75-85 percent (Yawn, 2015), others have reported 60 percent with waste-to-energy and composting additions getting it to 90 percent (Montgomery, 2016). When looking at the forms IREP submitted with their $28 per ton bid the recovery rates were estimated at 80 percent or better for mixed paper, 90 percent or better for OCC, tin, steel, and aluminum cans, and 85 percent or better for plastics. Kyle Mowitz, the CEO, claimed at a conference in November of 2014 that the numbers were 95 percent for mixed paper, 97 percent for OCC, 94 percent for tin and steel cans, 90 percent for aluminum cans, and 96 percent for plastics currently; while having no rejected loads, running 32.36 tph, and having an overall diversion rate of 60 percent as of May (Smith, 2014). It is already odd that the estimations varied so much, but these are also unrealistic expectations if referencing what has been achieved in the past.

The next problem arose from the combination of those over optimistic expectations with over optimistic values, and over estimating total tonnages. IREP estimated revenue of $9.2 million on 125,000 TPY of MSW using the output values in table 1. These were huge mistakes because they were only guaranteed 100,00 tons and these were current market values instead of taking a long run average approach and making a safe low-end estimate which is standard for a facility with an expected life of 20+ years.

	FOB Montgomery Pricing	
	Jan-13	Average 2012
OCC	$115/Ton	$130/Ton
Mixed/Soiled	$60/Ton	$70/Ton
Cartons	$30/Ton	$30/Ton
PET	$0.18/lb	$0.20/lb
HDPE - Color	$0.23/lb	$0.21/lb
HDPE - Natural	$0.33/lb	$0.29/lb
Mixed Plastic (3-7)	$0.06/lb	$0.04/lb
Aluminum Cans	$0.79/lb	$0.70/lb
Tin/Steel Cans	$0.04/lb	$0.03/lb
Metal - Ferrous	$0.06/lb	$0.06/lb
Metal - Non Ferrous	$0.19/lb	$0.16/lb

Table 1: FOB Montgomery Pricing

According to Van Dyke Recycling Solutions (VDRS), a MRF manufacturer that competes with Bulk Handling Solutions (BHS) that IREP used, revenue should have been estimated at $4.9 million at the time, which used lower output values and 100,000 tons per year to calculate. On top of this the facility was estimated at just over $23.1 million and ended up being in the ballpark of $32 million when the municipality took it back over. Since they used their expected revenue of $9.2 million to calculate their offer of $28/ton to the city, it is obvious they were way over leveraged from day one. They should have bid much higher due to them overestimating recovery rates, overestimating output prices, underestimating facility cost, and some say overestimating ability to sell dirty goods.

MWPF's can have a hard time having a clean output of fibers and many have claimed that their overestimation of ability to sell this paper is what sunk IREP. Fran McPoland with the Paper Recycling Coalition said that "some corrugated paper was being bought from IREP, but with the market at a low, clean, quality paper is at a premium. Many weren't buying what IREP was selling (Yawn, 2015, p. 24)." Reports to bondholders indicated that the revenue from the sale of OCC, mixed/soiled fiber, PET, HDPE, mixed 3-7 plastics, aluminum cans and ferrous metals were over $1.9 million for the 8.5 months of operation in 2014 and can be seen broken down in table 2 (Paben, 2016).

Series 2013AB

Recyclable Products/Marketing – FOB Montgomery Pricing

For Fiscal Years Ended December 31, 2014

OCC	$	188,329.00
Mixed/Soiled	$	397,905.00
Cartons	NA	
PET	$	367,941.00
HDPE - Color	$	152,129.00
HDPE - Natural	$	199,982.00
Mixed Plastic (3-7)	$	61,645.00
Aluminum Cans	$	387,400.00
Tin/Steel Cans	NA	
Metal - Ferrous	$	168,396.00
Metal - Non Ferrous	NA	

Table 2: Recyclable Products/Marketing - FOB Montgomery Pricing

This would appear to say that they weren't having a problem with contamination.

IREPs failure was devastating to Montgomery's financials. According to Crabb, Montgomery raised the garbage collection fees for the 70,000 households in the city to generate more than $2 million each year to put towards the facility (Paben, 2016). The deal had IREP being paid $2.8 million ($28/ton and 100,000 tons) a year for taking that amount of trash, but they had to repay the municipality on a graduated scale for every ton they sent to the landfill. After one year of operation, IREP owed the county $2.5 million for all the waste they sent to the landfill, according to Crabb. Crabb also said the city didn't make them pay it, "We actually forgave an excess of $2.5 million of garbage they were sending back to the landfill, because that percentage got to be so significant (Yawn, 2015, p. 32)." At the end of it all, IREP earned a mere 10 percent of its projected profit while also being treated to more than $3 million in concessions. This graduated scale will help calculate estimates of the true recovery rates of the facility.

It will also be helpful to analyze operating statements. According to publicly available documents shown in table 3, IREP incurred an operating loss of $5.1 million on $3.9 million in revenue in 2014 (IREP, 2014). If you include interest expenses, the net losses rise to $6.4 million. Mowitz claimed that the volume received from the city was sometimes as much as 40 percent lower than the promised amounts (120,000 *.6=72,000). However, the feedstock supply agreement was written so IREP couldn't declare a city default on low volumes until after a year had passed (Paben, 2016). IREP left 18,210 tons of organic waste at the facility that would have earned the city more than $600,000 in tipping fees if the company had taken it to the landfill. In the final year of operation, the facility received 78,000 tons of trash from Montgomery and another

24,000 tons they had brought in from other areas. It was later estimated the facility would have needed 150,000 tons to be profitable (Yawn, 2018). That is an interesting figure, but no articles could back up that profitability target claim.

IREP-MONTGOMERY MRF, LLC
Statement of Operations
Year Ended December 31, 2014

Revenues	$ 3,981,473.94
Direct Expenses	5,152,718.94
Gross loss	(1,171,245.00)
Selling, General, and Administrative Expenses	3,932,418.58
Operating loss	(5,103,663.58)
Other Income (Expenses)	
Interest income	4,150.12
Interest expense	(1,318,667.98)
	(1,314,517.86)
Net loss	$ (6,418,181.44)

Table 3: IREP Statement of Operations (IREP, 2014)

I created a recovery estimate shown in table 4 based on the graduated scale I obtained from Crabb, assuming the 18,210 tons of compost was for the entire 18-month life span, the $1.9 million was for the 8.5 months from April-December 2014, and the 78,000 plus 24,000 tons was for the 12 months of November-October 2015. For revenue per ton, let’s assume that the $1.9 million in 8.5 months was based on 55,250 tons (78000/12*8.5). I will also assume that since in the final 12 months that they got 78,000 from the city that the first 12 months was probably less since they would have complained, I will use 70,000 as my low estimate and the best-case scenario would be the same as the last 12 months 102,000. So, for the full first year where they had $2.5 million in dumping fees I will assume they made about $2.4 million (1.9/55250*70000) from selling recyclables. This means that the amount of material sold was only 4.9-30.3 percent based on these assumptions and the graduated scale. However, it also means that they made $77-700 per ton for what was sold. These are huge ranges, but what it does tell us is that even though the recovery was only 30 percent at best, they were succeeding in making a good amount per ton, $77, at worst. This could also mean that they were achieving 60 percent recovery but could only sell half of these commodities due to the contamination. This lends more validity to the contamination problem.

				Dollars Owed to Landfill			
Graduated Scale				According to Kyle	From City in Final Year	Stated in Contract	With 24,000 Brought In
Range		N	Per/ton	70,000	78,000	100,000	102,000
0%	15%	15%	$ 28.00	$ 294,000	$ 327,600	$ 420,000	$ 428,400
15%	25%	10%	$ 33.60	$ 235,200	$ 262,080	$ 336,000	$ 342,720
25%	35%	10%	$ 42.00	$ 294,000	$ 327,600	$ 420,000	$ 428,400
35%	100%	65%	$ 56.00	$ 1,676,800	$ 1,582,720	$ 1,324,000	$ 1,300,480
Money Owed to Montgomery				$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000
			Per/ton	Tons Landfilled			
			$ 28.00	10,500	11,700	15,000	15,300
			$ 33.60	7,000	7,800	10,000	10,200
			$ 42.00	7,000	7,800	10,000	10,200
			$ 56.00	29,943	28,263	23,643	23,223
				54,443	55,563	58,643	58,923
				Results			
			Tons Recovered	15,557	22,437	41,357	43,077
			% Recovered	22.2%	28.8%	41.4%	42.2%
			Unsold compost	12,140	12,140	12,140	12,140
			% Sold	4.9%	13.2%	29.2%	30.3%
			Tons Sold	3,417	10,297	29,217	30,937
			Revenue	$ 2,400,000	$ 2,400,000	$ 2,400,000	$ 2,400,000
			Revenue/Ton	$ 702.34	$ 233.07	$ 82.14	$ 77.58

Table 4: My IREP Estimations

The bankruptcy at IREP isn't a gravestone for economically feasible MWPF. However, it did illustrate a handful of things. First, at best, only 30 percent of the total waste steam was recovered clean enough to sell in the form of fiber, plastic, and metal with compost adding another 12 percent. That is even for a city with no single stream recycling in program currently in place which means there was more valuable material left in the stream then there would be in Columbus and absolute best-case scenario, even counting the unsold and non-composted organics, it still only matched the 42 percent Columbus achieves without any more investment. This means that current technology isn't good enough to allow for a standalone MWPF to achieve the 70+ percent recovery wanted. Second it showed that if you want to have a standalone MWPF you must be very realistic with your estimates and there will need to be a lucrative deal with a municipality for a loan or tax/subsidy to make it possible. Finally, it is now much harder for Montgomery to switch to the idea of a single stream participation driven program. Which illustrates that this could erode the consumer consumption habits creating a worsening over time which may mean that even when the technology is there we may not want to utilize it. Interesting to note is that the shuttered facility has just been purchased with plans to start back up, if they will be successful and what there focuses will be are still yet to be seen (Staub, 2018, RePower). Now, it is important to further analyze this issue of contamination.

Chapter 5. Opposition to Mixed Waste Processing Facilities

The MWPF has been heralded by many as the idealistic image of what could make waste management simple and streamlined, but adoption rates have been low over the past couple of decades for several reasons. From the first Dirty MRFs of the 1990's to the most recent failed attempt by IREP-Montgomery in 2014, there have been too many barriers to overcome. The main concern surrounding MWPFs, as mentioned in the last chapter, is contamination, that is, the quality of recovered materials may be inferior to that of the single stream system.

The concern surrounding contamination has drawn a ton of opposition. Some of the opponents include the National Recycling Coalition and RIC members. The Paper Recycling Coalition gave a presentation back in 2015 on their opinion on the matter. One of their arguments is that since they create food packaging the contaminates that are present in MWPF do not allow for sanitary end products (McPoland, 2015). They see these three things as threats to the fiber supply: Waste paper/board from hospitals contaminated with bio- hazardous material; recovered paper/board which has been mixed with garbage destined for landfills and subsequently sorted out (rather than sourced from single and dual recycling streams), and secondary fiber from households containing used hygienic paper (kitchen towels, handkerchiefs, facial tissue, toilet paper and diapers) (McPoland, 2015). All these concerns limit the adoption of MWPFs.

The Paper Recycling Coalition also provided an exert from a contract with an actual MWPF,

> XXXXX commodities are secondary post-consumer materials, recovered manually from municipal solid waste, and will not be technically perfect or completely free of contamination. It is the sole responsibility of the Purchaser to determine the suitability of XXXXX materials for his purposes. XXXXX will accept no responsibility for materials sold by XXXXX as a certain grade and then resold by Purchaser as a higher grade, or for materials marketed by Purchaser to third parties or end users that have zero tolerance for items commonly found in municipal solid waste. In all such cases, Purchaser assumes sole responsibility for all costs associated with rejections, downgrades, sorting, disposal, and/or claims of any kind (Mcpoland, 2015, p. 13).

This was to illustrate the fact that the product was not clean and that they were shifting responsibility to the purchaser. This doesn’t seem like a valid argument for why it shouldn’t be allowed. What it shows is that those recovering the waste are being straightforward and honest. These outputs may need to be cleaned more to be suitable for food products, sold to companies that aren’t worried about that issue, or potentially cooked to kill contaminates and to be fit for compost without the concern for seepage.

The big players that are opposing this make it clear that contamination needs to be dealt with. More buyers from these systems and operators of the systems need to come forward with testimonials and data to alleviate these concerns. However, some operators have already attested to these issues in the past as consulting firm Gershman, Brickner & Bratton, Inc (GBB) states,

> The facilities at Newby Island, Greenwaste, and Montgomery have been selling their recovered recyclables, including fiber, and it was indicated by Infinitus that the price was “hi-side,” especially for containers and metal. On the other hand, the Medina County MWPF has recently been idled and come under scrutiny because of the county’s low recycling rate. However, the fiber, plastics and metals recovered from the Medina County MWPF have been able to be marketed by their facility operator over the past 20 years. It is an older facility but the operator

> and paper market both indicated to GBB that the fiber recovered from their manual sort lines had always been marketable. It is important to understand that the Medina system is old and has none of the design features or unique specialty equipment that is being installed in modern MRFs and MWPFs (Gershman, 2015, p. 39).

Infinitus is IREP and this statement from them is only true because they only sold the cleanest of what was pulled out, proved by the breakdown of their revenue in the previous chapter. It should also be assumed that Medina is only selling the best of the best which would explain the ability to stay afloat financially with such low recovery rates. The current scales seem to show strong opposition outweighing little hard proof from the supporters.

Another thing to keep in mind when looking at MWPFs is the consumer participation. The fact that none is required is both a blessing and a curse. It allows for an immediate rise to 100 percent “participation”, but it also means that there is no education and a potential worsening in consumption habits (Peacock). This worsening has been seen in other technologies, for example, when airbags were first introduced there were more accidents and injuries because people felt safer and drove more recklessly. This can also be seen in the bystander effect and the Milgram shock experiments which both showed how people act less carefully when they think it is someone else’s problem. These are just examples and assumptions because tests that would allow some degree of certainty of consumers reactions and habit changes would take a lot of surveying and be a whole other research thesis.

The opposition to MWPFs is also strengthened by the lack of success in Houston,

> a city of 2.2 million with just a 6-percent recycling rate, even a $1 million grant and $50,000 of in-kind support from Bloomberg Philanthropies Mayors Challenge

> has not been able to get its “One Bin For All” project off the ground—at least, not yet (Quinn, 2016, p. 36).

This shows that not only does it look unlikely for the technology to be good enough, but even when it is it may be better to avoid it.

Not only are MWPFs struggling with this issue, but even the biggest single stream recycling companies are struggling. CNBC reported that from 2014 to 2016 Waste Management has closed 21% of its recycling facilities (totaling 30 facilities), with no intentions to open any new ones—however a few more may close in the near future (Musulin, 2016). The MRF closures are a result of the overall recycling industry struggling to stay profitable. Waste Management's Newark Area Vice President Tara Hemmer told CNBC that a bale of aluminum cans that used to sell for more than $2,000 per ton now sells for $1,100 per ton. Due to low oil prices, it is simply more cost-effective for manufacturers to make virgin materials like plastic than to purchase recycled materials (Musulin, 2016). Another big reason for this problem is how cheap it is to landfill material in flat states like Ohio where tipping fees are around $40 versus other regions where it can be in the $70 range. Additionally, California has large subsidies, for example, in Ohio Rumpke may sell a ton of aluminum to Anheuser-Busch for $1400, but in California the government adds on $2000 to that in California Redemption Value (CRV). If facilities with all recyclables are struggling, then it seems logical that a MWPF that had to dig through more waste to get to it couldn’t stay profitable.

Chapter 6. Review of End Products

It is important to examine each end product in detail because with a changing political landscape surrounding single use materials and China regulations, profitability of waste management will no longer be as achievable as in the past. Some estimates say that about 20 percent of current waste is believed to be impossible to recover such as diapers, painted Christmas trees, and skateboard wheels, and another 10 percent has no current recovery system (ex. toothpaste tubes, sandwich bags, lip balm tubes, drink pouches, etc.) (Timpane). The 70 percent that is currently readily recoverable and/or compostable will largely drive the overall revenue from recovering waste. Table 5 gives a summary of some of the important factors of these potential end products that will be discussed in detail in the next subsections.

Material	**Cleanable**	**Environmental/ Energy Saved**	**Market Demand**	**Cost to recover**	**Portion of total stream**
Plastic	Potential	High	High, unpredictable	High	16%
Metal	Potential	High	High, unpredictable	Low	4%
Fiber (paper)	No	Medium	High, unpredictable	High	28%
RDF/Mass Burn	n/a	Low	Low, predictable	Low	100%
Organics	n/a	High	High, predictable	Low	52%

Table 5: Summary of End Products

The Institute of Scrap Recycling Industries (ISRI) releases a Scrap Specifications Circular at least once per year, but as often as quarterly, that outline standards for businesses in the recovery and recycling realm to look to for expected qualities of material. The guidelines presented in Appendix A are based on the April 16, 2018 update, but these guidelines are just benchmarks and industry standards. The guidelines that truly matter are that of the company you are trying to sell to, some may be more lenient than the standard and others may be stricter. Each one of these end products is affected by the organic portion of the waste stream that get the other materials wet and dirty. This is also where the new, more stringent, requirements in China are causing problems.

Plastics, Metals, and Fibers

To better understand the issues that arise with the contamination in MWPFs it is important to read the excerpts from the Scrap Specifications Circular in Appendix A that describe what are considered standard expectations. It is clear to see that a MWPF that allows for recyclables to be in a dumpster with wet organic matter and other contaminates would make these standards extremely difficult to meet, maybe even impossible for fibers.

The market for metals is the strongest because it is more valuable compared to paper or plastics, it is more cost effective to recover, and it is easier to process back into raw material. Plastics can usually only be recycled 1-2 times, fiber 5-7 times, and metals and glasses pretty much infinite (Sinai, 2017). Another important detail is the energy saved versus making it out of virgin materials, aluminum is the most efficient source and saves about 95 percent of the energy, while glass is the least efficient and still saves 30 percent. Plastic and metal waste sent through a MWPF would require a pre-wash system to meet standards or need to be sold at a steep discount compared to single stream facilities if recyclers decided to buy them and clean them themselves. Another point is the unnecessariness of single use plastics that are filling up our landfills and oceans and killing sea life; all while more sustainable fiber and metal alternatives are available.

As stated, fibers are the big bottleneck when it comes to MWPFs. The contamination effects them much worse than plastics and metals because those can be cleaned better and what is left can be burned off because they are recycled at high temperatures. Paper is pulped and the oil and other contaminates float to the top with the paper leaving holes in the parchment when dried and there are currently no techniques to remove the oil efficiently. Fran McPoland of the Paper Recycling Coalition said, "This is pretty much alchemy. It's just an impossible situation to say you can logically contaminate this material and by some magic process separate it back (Yawn, 2015, p. 25)." However, a mill could potentially send the paper back through the process, but then they would have to pay less because they have double the operating costs as a regular mill. However, if other end product uses for this spotted paper can be found that doesn't require it to be quite as sturdy or attractive then it wouldn't matter, and it would be cheaper for the customer to buy than the higher quality alternative. These fibers could also just be composted with the food, yard, and wood waste to help get the carbon/nitrogen ratio right.

Waste to Energy: Refuse-Derived Fuel and Mass Burn

Waste-to-energy technologies have become abundant and commonly used in trash disposal. Sweden has even bragged that it does such a good job of handling trash that it imports it from neighboring countries. However, is the act of turning trash to energy environmentally friendly? Most of the numbers say no, according to the US EPA, burning waste has a larger average nitrogen and sulfur oxide emission level than natural gas, but less than coal (Leblanc, 2018). However, it is much worse than renewable energies like solar and wind, and it takes away non-renewable resources that could have been recycled for reuse. For these reasons it is currently not ideal to include a mass burn or RDF system at a future Columbus facility at this point. It isn't the best-case scenario and using it would put off finding a better solution. To add more validity to this claim just look to the city of Houston.

Back in 2014 the city of Houston, Texas was taking proposals for landfill diversion strategies. The Zero Waste Houston Coalition created a study to show why a proposal for a dirty MRF with an incineration component was not the best choice. The main conclusions from the report read as follows,

> For every ton of household garbage, there are as many as 71 tons of materials discarded upstream during the extraction, refining, manufacturing and distribution of those materials. Incineration does nothing to change the upstream production of waste, which accounts for a larger quantity of greenhouse gas emissions than landfilling. To rely on waste burning without addressing waste reduction is ill-advised, and Denmark missed their climate change goals because of their reliance on phased incineration (Zero Waste Houston, 2014, N/A).

It is difficult to argue with those facts against both RDF and Mass Burn technologies, but AD with organics may be a different, more sustainable, story.

Organics and Anaerobic Digestion

The organic fraction of the municipal waste stream in Columbus is very important for recycling rates because it makes up the biggest portion of the stream. The main forms that organic waste comes in are food, wood, yard, and fiber. There are a couple mainstream solutions to dealing with the organic waste. One being to use it for daily cover for the landfill since soil or another cover will need to be used anyway, another option is to create compost/soil amendment out of it for growing food or improving soil structure, and finally you can create energy out of it through anaerobic digestion which can also be done while creating compost/soil amendment. It is promising that there are so many output options, but for an organic focus to be sustainable it is important to look at the potential of each.

Anaerobic digestion is used for organics, while the other wastes like plastic are burned. This is because of the high moisture content, “AD is a controlled process that allows microbes to break down organics in an environment devoid of oxygen. The process produces a biogas that can be used for electricity production or processed into compressed natural gas (CNG) (Gershman, 2015, p. 10).” When it comes to AD there are a multitude of different systems available to use.

A possible AD contender for use in Columbus was Zero Waste Energy Development Company (ZWEDC) which operates the largest anaerobic digestion facility in the world. However, it is not economically effective without a large subsidy like the one they receive from the state of California. ZWEDC’s facility can handle up to 90,000 tons of organics per year, creating 6,778 MWh of electricity and 30,000 tons of finished compost (Zero Waste Energy). The compost that comes out of the system is not finished and ready for sale, it must be sent to a sister facility to mature in an AG-bag for another 3 months or so. The cost of building the facility was $55 million and they are depreciating that amount over 15-20 years, this expense is included in their operating expense of $13 million per year. They are currently reporting a $500,000 deficit every month and the facility currently has 23 full time employees. Working under the assumptions that they are selling electricity for about $.155 per kilo-watt hour and compost for a hefty, and unlikely, $50 per ton, and their operating expenses include everything, they are getting a subsidy of almost $4.5 million dollars per year on just 90,000 tons of organic waste. This is not something Columbus should look to imitate.

A potential composting contender was Sevier Solid Waste, Inc. (SSWI) Compost Plant, they are the largest municipal solid waste compost facility in the U.S. They use in-vessel digesters and claim that after 28 days they have Grade A compost. They process approximately 375 tons per day with 60 percent of that composted to create over 70,000 tons of compost for local farms, erosion control, and many other uses listed on their websites compost page including: starting new lawns, top dressing, mulching, flower beds, tree planting, and topsoil enrichment (Sevier). The other 40 percent is screened off and taken to an onsite MRF. They have a prototype of a cleaning system that removes compost from the metal before it is baled and from the plastics before sale, but it is not yet meeting their buyer’s specifications. However, this organic focus allows them to successfully divert 70 percent of their waste stream, so it must have some validity to it

(Sevier). An advantage they have is being a tourist heavy area, so their waste stream has a much different composition than that of a city like Columbus, but since Columbus has a successful single stream system in place there is an opportunity for this style of system to be successful and AD can always be added.

When it comes to maturing the compost, there is a company called, Green Mountain Technologies (GMT), that has two large-scale systems that can process about 300 TPD or about 110,000 tons per year. The one option is an Aerated Static Pile system that would cost $1,500,000 and the second is a Turned Aerated Pile that would cost $2,000,000 plus $500,000 for equipment. The Static system would require three operators and the Turned system would require two operators and cover 6 acres. The estimated lifespan is 20 years for pads and 10 for turners and blowers. The turned system would be optimal even though it has more upfront costs because it requires less works, less space, and matures the compost more quickly.

There are different grades of compost that come with different uses and price tags, but there is also a ton of variance just within Grade A. Branded, Grade A, bagged organic compost such as EcoScraps is $6.47 for a one cubic foot bag (23 pounds) which would be $562 a ton vs. SSWI giving theirs away for free. A typical price range for bulk compost ranges from $10-$40 a ton. How high quality of mix we could make from this, and how we decided to market/position it, would have a huge effect on price.

Finally, since it seems as if a facility like SSWI with GMT pads would show great promise it is important to keep in mind a utilization plan. Plastics and metals are sold much differently than composts and we would create hundreds of thousands of tons of it.

Even though there are multiple end uses none have the scale that farmland does. If test plots could be created that prove this compost improves crop yields, then there would be an immediate end use for this massive amount of material and little risk to the facility.

Chapter 7. Cost to Columbus

There are two options available to supplement Columbus's single stream efforts, a MWPF that focuses on a last resort sort of plastics and metals and one that focuses on organics. The important thing is which one has the best tradeoff between benefits (landfill value and resale value) and costs (the price to construct and run). SWACO landfills around one million tons of waste a year which would take a facility that could process 200 tons per hour running 20 hours a day, 250 days per year. The size of the cost with adding waste processing facilities is large, and the total amount that can be diverted is difficult to estimate, making it a risky project. To be more realistic I propose we assume that this would be a three-phase plan with the first phase being around 300,000 tons, or almost one-third of the waste stream, and what I will use in my calculations.

Mixed Waste Processing Facility Focused on Plastics and Metals

The most important things regarding the financials of this plan are the cost of the facility, the expected labor expense, the expected recovery rates and market values, and the expected energy cost. These numbers will allow me to estimate the profitability, or lack thereof, and the loan required to construct the facility. I contacted the five largest MRF manufacturers in the U.S. to estimate the cost of the facility. Some responded and provided cost estimates for me. I used a different approach for those that did not respond, I used data from their past projects to estimate the costs. The summary of the costs are seen in Table 6.

(Millions)	Machinex	Stadler	CP Group	VDRS	BHS
Equipment	$18	$45	$10	$25	$35
Site & Building	$15	$20	$15	$15	$15
Total	$33	$65	$25	$40	$50
Claimed Recovery	90% of recoverable About 15-20%	90% of recoverable About 15-20%	15-20% of stream if stand alone So more likely 7.5-10%	90% of recoverable About 15-20%	90% of recoverable About 15-20%
Comp.	Company Estimate	Company Estimate	Sun Valley 2-50 TPH $11 when built, $15 today, focused on RDF and BTU value, maybe 20% recovery	Current 56 TPH single stream facility	Athens Services 70TPH-$50 (Partial) IREP 30 TPH- $32

Table 6: MWPF Prices

These numbers show a large divide in the expected cost for such a facility, but also allow very different recovery expectations. I will be using $40 million for this comparison because this is close to the estimates from VDRS and Machinex. I chose this because they are neither the lowest nor the highest across the group and is close to the average across all five.

To estimate the employee count I reached out to manufacturers of the facilities, management of currently operational single stream and mixed waste facilities and, utilized IREPs numbers. I converted these numbers up to my 300,000 tons needed and used them to estimate my expected employee count. Table 7 lays out the information I gathered after conducting the interviews.

				Conversion to TPY		300,000		TPH	60
	Rumpke	IREP	Vanderlinde	Green Waste	VDRS	Athens Services	Stadler	Placer	Machinex
Plant Manager	-	4	3	-	3	-	-	-	-
Plant Supervisor	3	2	-	3	3	-	-	-	3
Shift Supervisor	3	4	-	-	3	-	-	-	-
Weigh Master	-	4	-	-	-	-	-	-	-
Eq. Operator- Loader/Tractor	-	4	-	1	9	-	-	-	3
Wheelloader/Exc Cost/Hour	-	-	-	-	-	-	-	-	-
Wheelloader/Exc Fuel Consumption	-	-	-	-	-	-	-	-	-
Eq. Operator- Bailer	20	4	3	2	6	-	-	-	3
Eq. Operator- Forklift	-	4	6	1	9	-	-	-	3
Forklift Cost/Hour	-	-	-	-	-	-	-	-	-
Forklift Fuel Consumption	-	-	-	-	-	-	-	-	-
Drivers	-	6	-	-	-	-	-	-	-
Maintenance Supervisor	-	-	-	-	3	-	-	-	-
Maintenance Mechanics	20	19	-	-	18	-	-	-	9
Sort Lead	-	4	-	-	-	-	-	-	-
Security	-	2	-	-	-	-	-	-	-
Tipping Floor Attendant	-	6	-	-	-	-	-	-	-
Bail Attendant	-	9	-	-	-	-	-	-	-
Sorters	113	150	18	18	90	-	30	-	90
General Labor- Can Dumpers	-	9	6	-	87	-	-	-	-
General Labor- Janitors/Grounds Keepers	-	9	-	-	-	-	-	-	6
Clerical Positions	-	-	-	-	3	-	-	-	-
	-	-	-	-	-	-	-	-	-
Total	160	242	36	24	234	152	-	175	117

Table 7: Labor Estimations for 300,000 Tons Per Year (TPY)

The biggest wildcard in this is the number of sorters and general labor required. As you can see across the board there is a big difference there, the difference is caused by two things: first, the level of automation of the equipment and second, the hopeful recovery rates. For example, Stadler has a highly automated and more expensive system that needs 30 sorters, but the less automated version needs 120 which would make operating expenses much higher. The Vanderlinde and Green Waste are so low because they aren't trying to achieve as high of a recovery rate because they also utilize mass burn that is environmentally harmful.

After this I estimated expected administrative roles of sales, accounting, and human resources. The next step was to find out competitive salaries for these positions and then to figure out how much benefits would add to compute an expected yearly salary expense. For my estimations in table 8 I assumed we would have a more automated system with two or three robots performing quality control.

Plant Position	Low	Avg.	High			Salary	Commission	Benefit:	Total	Comp.
Plant Manager	$ 54,000	$ 82,000	$ 116,000	$ 85,000	1	$ 85,000		130%	$ 110,500	$ 110,500
Plant Supervisor	$ 43,000	$ 63,000	$ 91,000	$ 65,000	3	$ 195,000		130%	$ 253,500	$ 84,500
Shift Supervisor	$ 32,000	$ 43,000	$ 71,000	$ 45,000	3	$ 135,000		130%	$ 175,500	$ 58,500
Weigh Master	$ 10	$ 14	$ 20	$ 28,080	3	$ 84,240		130%	$ 109,512	$ 36,504
Eq. Operator- Loader/Tractor	$ 11	$ 16	$ 24	$ 33,280	3	$ 99,840		130%	$ 129,792	$ 43,264
Wheelloader/Exc Cost/Hour					0	$ -		130%	$ -	
Wheelloader/Exc Fuel Consumption					0	$ -		130%	$ -	
Eq. Operator- Bailer	$ 11	$ 15	$ 24	$ 31,200	9	$ 280,800		130%	$ 365,040	$ 40,560
Eq. Operator- Forklift	$ 11	$ 13	$ 18	$ 27,040	9	$ 243,360		130%	$ 316,368	$ 35,152
Forklift Cost/Hour					0	$ -		130%	$ -	
Forklift Fuel Consumption					0	$ -		130%	$ -	
Drivers	$ 14	$ 18	$ 25	$ 37,440	3	$ 112,320		130%	$ 146,016	$ 48,672
Maintenance Supervisor	$ 31,000	$ 58,000	$ 79,000	$ 55,000	3	$ 165,000		130%	$ 214,500	$ 71,500
Maintenance Mechanics	$ 13	$ 20	$ 28	$ 41,600	12	$ 499,200		130%	$ 648,960	$ 54,080
Sort Lead	$ 11	$ 14	$ 17	$ 29,120	0	$ -		130%	$ -	
Security		$ 27,000		$ 27,000	0	$ -		130%	$ -	
Tipping Floor Attendant	$ 9	$ 12	$ 15	$ 24,960	6	$ 149,760		130%	$ 194,688	$ 32,448
Bail Attendant	$ 9	$ 12	$ 15	$ 24,960	6	$ 149,760		130%	$ 194,688	$ 32,448
Sorters	$ 9	$ 12	$ 15	$ 24,960	90	$ 2,246,400		130%	$2,920,320	$ 32,448
General Labor- Can Dumpers	$ 9	$ 12	$ 15	$ 24,960	9	$ 224,640		130%	$ 292,032	$ 32,448
General Labor- Janitors/Grounds Keepers	$ 9	$ 12	$ 15	$ 24,960	4	$ 99,840		130%	$ 129,792	$ 32,448
					Total	$ 4,770,160		130%	$ 6,201,208	
Administrative										
Sales	$ 20,000	$ 39,000	$ 79,000	$ 40,000	2	$ 80,000	$ 60,000	130%	$ 164,000	$ 82,000
Accounting/Finance	$ 38,000	$ 52,000	$ 69,000	$ 55,000	1	$ 55,000		130%	$ 71,500	$ 71,500
HR	$ 41,000	$ 52,000	$ 73,000	$ 45,000	2	$ 90,000		130%	$ 117,000	$ 58,500
					Total	$ 225,000		130%	$ 292,500	
Composting										
Equipment Operators	$ 11	$ 15	$ 24	$ 31,200	0	$ -		130%	$ -	
					Total	$ -		130%	$ -	
					Total	$ 4,995,160		130%	$6,493,708	

Table 8: Plastic and Metal Focused Labor Expectations

Table 8 outlays the labor breakdown expected at a high-tech facility including salary, commission, and benefits with a total labor expense around $6.6 million. However, some manufactures did claim to be much less than some of these numbers, but to reiterate, IREPs biggest problem was not being safe with estimates so I will be excluding the outliers.

Recovery rates were another thing that IREP overshot on. I looked at the opinion of two of the top consulting firms in the field and combined that with one machine manufacturer that gave me a breakdown of all their safe estimates. I decided what I felt was a safe estimate given the information in table 9 from Machinex, RRS, and GBB and came out with the rates you will see in the percentage reclaimed column of table 10.

	High End- Burns & MacDonnel	RRS Estimate*	Low End - Cascadia Palo Alto Study	GBB - Low	GBB - High	Machinex	For Machinex
% Recovered of Total Available	%	%	%	%	%	%	
OCC	90%	10%	7%	65%	75%	40%	
Other Fibers (News/Office/Mixed)	80%	10%	7%	50%	70%	10%	Positively sorted to produce the cleanest fiber possible to compete with single stream
PET	80%	70%	60%	85%	90%	80%	
HDPE (Natural)	80%	70%	60%	85%	90%	80%	
HDPE (PIG)	80%	70%	60%	85%	90%	80%	
Mixed Plastic	80%	70%	60%	75%	80%	25%	No automation to recover because value isn't there
Bags and Film	80%	15%	15%	25%	40%	25%	No automation to recover because value isn't there
Aluminum	90%	90%	80%	90%	95%	85%	
Stell/Tin Cans						85%	
Ferrous	90%	90%	80%	90%	95%	60%	
Non-Ferrous						60%	
Organics Foodwaste, Yardwaste				80%	90%	70%	
Container Glass						90%	
Textiles						10%	No automation to recover because value isn't there
Wood						20%	No automation to recover because value isn't there

Table 9: Recovery Estimations (Gershman, 2015)

The below table will estimate the expected revenue to be generated by the facility from the sale of recovered materials. Material prices were estimated based on historical prices obtained from the former Executive Director of SWACO, Mike Long. Depending on the material and how long it had been being tracked there was 2-12 years of monthly prices that were used to create safe expected estimates for the expected average value over the next decade an example of the work can be seen in Appendix C.

General Material Category		Tonnage Available	Machin e UpTime	Tonnage Loaded	Percentag e Reclaimed	Tonnage For Sale	Value Per Ton Estimate	Estimates of Potential Revenue
Fibers	Cardboard/OCC	111,626	0.90	100,463	0.10	10,046	$ 63.75	$ 640,454.18
	Newspaper	18,572	0.90	16,715	0.10	1,671	$ 34.00	$ 56,830.32
	Office Paper	27,369	0.90	24,632	0.10	2,463	$ 21.25	$ 52,343.21
	Other Mixed Paper	128,047	0.90	115,242	0.10	11,524	$ 21.25	$ 244,889.89
Subtotal		285,614						$ 994,517.60
Plastics	PET #1	27,858	0.90	25,072	0.70	17,551	$ 180.00	$ 3,159,097.20
	HDPE #2 - Natural	4,887	0.90	4,398	0.70	3,079	$ 500.00	$ 1,539,405.00
	HDPE #2 - Colored	14,662	0.90	13,196	0.70	9,237	$ 320.00	$ 2,955,859.20
	PVC #3	2,932	0.90	2,639	0.25	660	$ 20.00	$ 13,194.00
	LDPE #4	38,610	0.90	34,749	0.25	8,687	$ 20.00	$ 173,745.00
	Other Plastics	79,663	0.90	71,697	0.25	17,924	$ 20.00	$ 358,483.50
Subtotal		168,612						$ 8,199,783.90
Metals	Aluminum Cans	7,331	0.90	6,598	0.85	5,608	$ 1,100.00	$ 6,169,036.50
	Steel/Tin Cans	11,730	0.90	10,557	0.85	8,973	$ 40.00	$ 358,938.00
	Other Ferrous Metals	15,639	0.90	14,075	0.60	8,445	$ 40.00	$ 337,802.40
	Other Non-Ferrous Metals	6,353	0.90	5,718	0.60	3,431	$ 40.00	$ 137,224.80
Subtotal		41,053						$ 7,003,001.70
Uncategorized	Container Glass	26,880	0.90	24,192	0.90	21,773	$ -	$ -
	Yard and Pet Waste	57,670	0.90	51,903	0.50	25,952	$ -	$ -
	Textiles	78,197	0.90	70,377		-	$ -	$ -
	Food Waste	124,626	0.90	112,163	0.50	56,082	$ -	$ -
	Wood	52,783	0.90	47,505	0.50	23,752	$ -	$ -
Subtotal		340,156						$ -
MISC.	Trash	150,000	0.90	135,000	1.00	135,000		$ -
Subtotal		150,000						$ -
Total		**985,435**						**$ 16,197,303.20**

Table 10: Plastic and Metal Focused Expected Revenue

As far as energy use goes my friends at Rumpke helped me estimate what to expect. Brad Dunn, the Recycling Operations Manager for their Cincinnati MRF said that their average monthly electrical service expense for the plant is about $34,000. That is on a 56 TPH line that is processing about 16,500 tons per month making the cost about $2.06 per ton. However, he also said it was important to remember that these costs are also for supporting factors like lighting and safety equipment. So, at $2.06 per ton a 300,00-ton facility would be about $618,000 per year.

Mixed Waste Processing Facility Focused on Organics

As shown below in table 11 the labor will be much less intensive then on the IREP style MWPF.

Plant Position	Low	Avg.	High			Salary	Commission	Benefit:	Total	Comp.
Plant Manager	$ 54,000	$ 82,000	$ 116,000	$ 85,000	1	$ 85,000		130%	$ 110,500	$ 110,500
Plant Supervisor	$ 43,000	$ 63,000	$ 91,000	$ 65,000	2	$ 130,000		130%	$ 169,000	$ 84,500
Eq. Operator- Compost	$ 11	$ 15	$ 24	$ 31,200	6	$ 187,200		130%	$ 243,360	$ 40,560
Eq. Operator- Forklift	$ 11	$ 13	$ 18	$ 27,040	2	$ 54,080		130%	$ 70,304	$ 35,152
Maintenance Mechanics	$ 13	$ 20	$ 28	$ 41,600	2	$ 83,200		130%	$ 108,160	$ 54,080
Tipping Floor Attendant	$ 9	$ 12	$ 15	$ 24,960	2	$ 49,920		130%	$ 64,896	$ 32,448
Discharge	$ 9	$ 12	$ 15	$ 24,960	5	$ 124,800		130%	$ 162,240	$ 32,448
General Labor- Janitors/Grounds Keepers	$ 9	$ 12	$ 15	$ 24,960	2	$ 49,920		130%	$ 64,896	$ 32,448
					Total	$ 764,120		130%	$ 993,356	
Administrative										
Sales	$ 20,000	$ 39,000	$ 79,000	$ 40,000	0	$ -		130%	$ -	
Accounting/Finance	$ 38,000	$ 52,000	$ 69,000	$ 55,000	1	$ 55,000		130%	$ 71,500	$ 71,500
HR	$ 41,000	$ 52,000	$ 73,000	$ 45,000	0	$ -		130%	$ -	
					Total	$ 55,000		130%	$ 71,500	
					Total	$ 819,120		130%	$ 1,064,856	

Table 11: Organic Focused Labor Expense

As far as cost of the facility goes SSWI just bought two new digestors from Citic Holdings in China. They were priced at $3 million for construction, $2 million for installation and teaching, and $750,000 for transportation from Shanghai to Tennessee. These are each capable of 90 tons per day and need to have off days for maintenance. To get to 300,000 tons using the same 250 days as the facility focused on plastics and fibers would take about 14 digestors. If two were a combined $5.75 million then we can assume some order quantity discounts would ensue, so I will use $35 million as a benchmark. This system will also require a place for compost to age which I will use GMTs technology for which can process about 300 TPD and cost $2,000,000 plus $500,000 for equipment. Since we will need the equivalent to 1.5 of these we will assume around $4 million. Plus, buildings, offices, and sifting equipment bringing the total to about $11 million with a grand total of $50 million.

My friends at SSWI helped for the energy estimate. They are spending about $35,000 a month on electricity between: lights, digestors (3 at $15,000), primary screen, conveyer belts, final screen, and baler. They have 3 digestors at $5,000 each so for 14 it should be estimated at $70,000 and the $20,000 in others is capable for more space then that since some of their digestors are currently off line so $20,000 times 3.5 quantity would be about $70,000 so a total of $140,000 a month. That is $1,680,000 per year.

Comparison

So, table 12 is what a comparison of the two facilities would look like with the expected yearly facility cost calculated in Appendix B.

Facility Focus	**Plastic & Metal**	**Organics**
Facility Cost	$ 40,000,000.00	$ 50,000,000.00
Expected Yearly Facility Cost (20-year loan at 5%)	$ (2,945,000.00)	$ (3,681,250.00)
Labor Expense	$ (6,493,703.00)	$ (1,064,856.00)
Energy Cost	$ (618,000.00)	$ (1,680,000.00)
Expected Revenue	$ 4,931,011.00	$ -
Net Profit/Loss	$ (5,125,692.00)	$ (6,426,106.00)
Approx. Percent of Stream Recovered	16% of 300,000 4.87% of total	50% of 300,000 15.22% of total
Tons Kept Out	48,000	150,000
Dump Fee/Ton	$ 39.75	$ 39.75
Landfill Value Saved	$ 1,908,000.00	$ 5,962,500.00
Economic Profit/Loss	$ (3,217,692.00)	$ (463,606.00)

Table 12: Final Comparison

However, it is also important to point out the main assumptions I made to make this accurate, as well as, what would have to happen to get organics to profitability or to have plastic and metal become the better choice. To make this accurate the assumptions that would have to hold true are that electricity, fuel, and metal prices along with labor required, labor expense, and interest rates would all need to hold relatively stable over the next year. For Organics to get to profitability we would need to see the cost of digestors come down, the efficiency of energy use to improve, or be able to sell compost, (instead of giving it away for free) metal, plastics, or energy from AD. For plastic and metal to become more profitable than the organic focus, sorting and cleaning technologies would have to get immensely more efficient, cheaper, and better which may be feasible with advancements in artificial intelligence and robotic automation. However, that is not even considering the potential effect to consumption habits making it undesirable.

To supplement the financials there are also other factors that make an organic focus a better choice. As mentioned we do not want to erode the current single stream participation rate because it is still better for the environment and an organic focus wouldn't let consumers believe we recycle for them. Plus, recyclables in a MWPF are already dirty at the beginning so if we can invent a cleaning system we might as well utilize it when they are even dirtier post organic.

Additionally, Columbus is the perfect testing ground for multiple reasons. There is already a single stream system in place allowing for organics to be the focus. There are two knowledgeable resources in The Ohio State University and Rumpke. There are economies of scale due to all the waste already going to SWACO. There is an immediate need for improvement because Columbus's projected growth will lead to more waste. And finally, SWACO is actively interested, as noted by what their director of innovation said to me when I mentioned this research and my idea to create test plots at the landfill to measure potential yield increases, "...we agree that organics is an issue and opportunity. The project could be a benefit to SWACO in expanding our knowledge and we would like to pursue discussions with you to assist with this research." So, not only does this system have potential to extend the landfill life, but Columbus is the perfect location and it would be easy to do a proof of concept.

Chapter 8. Conclusion

We are experiencing a plateau in participation rates for recycling. Mass burning material for energy is worse for the environment than landfilling. MWPFs that try to take people completely out of the equation and theoretically raise "participation rates" to 100 percent do not currently have the technology to make them a viable option, due to contamination. Getting paper wet and dirty causes a huge problem in recycling it and plastic and metal have a similar, but less serious problem. So, as of now it seems like a single stream component will always be necessary. Some people tout mixed waste processing at the idealistic view of the future, but I believe the effect that will have on our consumption habits will be horrible as shown by examples in other technology and cognitive behavior tests. This was also help us keep a focus on lessening single use plastics for more sustainable fiber and metal alternatives.

Having one facility for the single stream efforts and one for the garbage, focused on organics, seems to be the right answer now and may always be the right answer. Technology will allow us to save more from this stream in the future like cleaning plastics and metals on the back end of the organic system.

The only thing that could trump this is what California is doing. Residents there must separate their waste into three bins: recycling, organics, and trash, plus there are large subsidies for recyclables. This would be ideal but is a long way off from legislation to require/allow that in Ohio. A facility like SSWI in Columbus would still be able to easily transition to that framework in the future with no loss to the city. This is due to using a phased approach, after seeing the failure of Team Gemini, that will would allow for there to be no machine idle time if we switched to a 3-bin approach because I would only build the facility up to 500,000-600,000 tons which is currently the portion of the stream that is organic. It is vital to keep these kinds of political and extraneous factors in mind because of the 20 plus year life span of these types of investments. What must be done moving forward is finding out what it would take to create a viable compost from the Columbus waste stream to use it on the farmland in the county.

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Appendix A: Institute of Scrap Recycling Industries Specifications

The standard specifications included in this Circular are intended to assist members in the buying and selling of their materials and products. These specifications are derived from many sectors of the metals, paper stock, plastics, glass, and electronics industries and are constructed to represent the quality or composition of the materials bought and sold in the industry. The specifications are internationally accepted and are used throughout the world to trade the various commodities. Parties to a transaction may specify particular variations or additions to these specifications as are suited for their specific transactions and for their individual convenience. Any deviation from the standard specifications, how- ever, should be mutually agreed to and so stipulated in writing by the par- ties to the transactions (Institute, 2018, p. 2).

Plastics - Unspecified materials must not exceed 2% of total bale weight. The bale should be free of any free-flowing liquid of any type. Shipments should be essentially free of dirt, mud, stones, grease, glass, and paper. The plastic must not have been damaged by ultraviolet exposure. Every effort should be made to store the material above ground and under cover. A good faith effort on the part of the supplier will be made to include only rinsed bottles which have closures removed (p. 33-42).

Ferrous Metal Scrap - Cleanness. All grades shall be free of dirt, nonferrous metals, or foreign material of any kind, and excessive rust and corrosion. However, the terms “free of dirt, nonferrous metals, or foreign material of any kind” are not intended to preclude the accidental inclusion of negligible amounts where it can be shown that this amount is unavoidable in the customary preparation and handling of the particular grade involved. Off-grade material. The inclusion in a shipment of a particular grade of iron and steel scrap of a negligible amount of metallic material which exceeds to a minor extent the applicable size limitations, or which fails to a minor extent to meet the applicable requirements as to quality or kind of material, shall not change the classification of the shipment, provided it can be shown that the inclusion of such off-grade material is unavoidable in the customary preparation and handling of the grade involved (p. 13-22).

Fiber- All paper must be packed dry with a moisture content of 12%which is deemed to be the maximum dry limit. Prior to shipment the buyer and seller shall agree to a moisture percentage and a method by which moisture is to be tested. The grading section defines the waste we would have as, 3. Zero Tolerance The term “Zero Tolerance” as used throughout this section is defined as: Any material that contains any amount of Medical, Organic, Food Waste, Hazardous, Poisonous, Radioactive or Toxic waste and other harmful substances or liquids (p. 26-32).

Appendix B. Loan Calculations

Year	Loan	Yearly Loan	Interest Rate	Yearly Interest	Payment	
1	$ 40,000,000	$ 2,000,000	4.5%	$ 1,800,000	$ 3,800,000	
2	$ 38,000,000	$ 2,000,000	4.5%	$ 1,710,000	$ 3,710,000	
3	$ 36,000,000	$ 2,000,000	4.5%	$ 1,620,000	$ 3,620,000	
4	$ 34,000,000	$ 2,000,000	4.5%	$ 1,530,000	$ 3,530,000	
5	$ 32,000,000	$ 2,000,000	4.5%	$ 1,440,000	$ 3,440,000	
6	$ 30,000,000	$ 2,000,000	4.5%	$ 1,350,000	$ 3,350,000	
7	$ 28,000,000	$ 2,000,000	4.5%	$ 1,260,000	$ 3,260,000	
8	$ 26,000,000	$ 2,000,000	4.5%	$ 1,170,000	$ 3,170,000	
9	$ 24,000,000	$ 2,000,000	4.5%	$ 1,080,000	$ 3,080,000	
10	$ 22,000,000	$ 2,000,000	4.5%	$ 990,000	$ 2,990,000	
11	$ 20,000,000	$ 2,000,000	4.5%	$ 900,000	$ 2,900,000	
12	$ 18,000,000	$ 2,000,000	4.5%	$ 810,000	$ 2,810,000	
13	$ 16,000,000	$ 2,000,000	4.5%	$ 720,000	$ 2,720,000	
14	$ 14,000,000	$ 2,000,000	4.5%	$ 630,000	$ 2,630,000	
15	$ 12,000,000	$ 2,000,000	4.5%	$ 540,000	$ 2,540,000	
16	$ 10,000,000	$ 2,000,000	4.5%	$ 450,000	$ 2,450,000	
17	$ 8,000,000	$ 2,000,000	4.5%	$ 360,000	$ 2,360,000	
18	$ 6,000,000	$ 2,000,000	4.5%	$ 270,000	$ 2,270,000	
19	$ 4,000,000	$ 2,000,000	4.5%	$ 180,000	$ 2,180,000	
20	$ 2,000,000	$ 2,000,000	4.5%	$ 90,000	$ 2,090,000	
21	-					Average Yearly Payment
Sum		$ 40,000,000		$ 18,900,000	$ 58,900,000	$ 2,945,000

Year	Loan	Yearly Loan	Interest Rate	Yearly Interest	Payment	
1	$ 50,000,000	$ 2,500,000	4.5%	$ 2,250,000	$ 4,750,000	
2	$ 47,500,000	$ 2,500,000	4.5%	$ 2,137,500	$ 4,637,500	
3	$ 45,000,000	$ 2,500,000	4.5%	$ 2,025,000	$ 4,525,000	
4	$ 42,500,000	$ 2,500,000	4.5%	$ 1,912,500	$ 4,412,500	
5	$ 40,000,000	$ 2,500,000	4.5%	$ 1,800,000	$ 4,300,000	
6	$ 37,500,000	$ 2,500,000	4.5%	$ 1,687,500	$ 4,187,500	
7	$ 35,000,000	$ 2,500,000	4.5%	$ 1,575,000	$ 4,075,000	
8	$ 32,500,000	$ 2,500,000	4.5%	$ 1,462,500	$ 3,962,500	
9	$ 30,000,000	$ 2,500,000	4.5%	$ 1,350,000	$ 3,850,000	
10	$ 27,500,000	$ 2,500,000	4.5%	$ 1,237,500	$ 3,737,500	
11	$ 25,000,000	$ 2,500,000	4.5%	$ 1,125,000	$ 3,625,000	
12	$ 22,500,000	$ 2,500,000	4.5%	$ 1,012,500	$ 3,512,500	
13	$ 20,000,000	$ 2,500,000	4.5%	$ 900,000	$ 3,400,000	
14	$ 17,500,000	$ 2,500,000	4.5%	$ 787,500	$ 3,287,500	
15	$ 15,000,000	$ 2,500,000	4.5%	$ 675,000	$ 3,175,000	
16	$ 12,500,000	$ 2,500,000	4.5%	$ 562,500	$ 3,062,500	
17	$ 10,000,000	$ 2,500,000	4.5%	$ 450,000	$ 2,950,000	
18	$ 7,500,000	$ 2,500,000	4.5%	$ 337,500	$ 2,837,500	
19	$ 5,000,000	$ 2,500,000	4.5%	$ 225,000	$ 2,725,000	
20	$ 2,500,000	$ 2,500,000	4.5%	$ 112,500	$ 2,612,500	
21	-					Average Yearly Payment
Sum		$ 50,000,000		$ 23,625,000	$ 73,625,000	$ 3,681,250

Appendix C. Example of Historical Prices

Recovered Material Historical Pricing					
CHICAGO (Midwest / Central)		Value According to Data			
Sheet:		Date Start	Date Finish	Min	Max
1. Metals Aluminum Cans (Sorted, Baled, ¢lb., picked up)		Apr-05	Dec-17	30	102
2. Metals Aluminum Cans (Loose, ¢/lb., dropped off at RC)		Jul-05	Dec-17	23.25	89
3. Metals Steel Cans (Sorted, Baled, $/Gross ton, picked up)		Nov-15	Dec-17	25	225
4. Metals Steel Cans (Sorted, Densified, $/Gross ton, dropped off at RC)		Nov-05	Dec-17	20	300
5. Metals Steel Cans (Sorted, Loose, $/Gross ton, dropped off at RC)		Apr-05	Dec-17	10	160
6. Glass Flint ($/ton del.)		Apr-05	Dec-17	10	33.63
7. Glass Amber ($/ton del.)		Apr-05	Dec-17	5	30
8. Glass Green ($/ton del.)		Apr-05	Dec-17	-2.5	15
9. Glass 3 Mix ($/ton del. as Recyclable or Disposable)		Feb-14	Dec-17	-23.14	7
10. PS 54 Mixed Paper (MP)	$/ton	Nov-16	Dec-17	30	95.94
11. PS 56 Sorted Residential Papers (SRNP)	$/ton	Nov-16	Dec-17	50	104.38
12. PS 11 Corrugated Containers	$/ton	Dec-02	Dec-17	15	180
13. PS 37 Sorted Office Paper	$/ton	Dec-02	Dec-17	85	300
14. Plastics PET (Baled, ¢/lb., picked up)		Apr-05	Dec-17	1	38
15. Plastics Natural HDPE (Baled, ¢/lb., picked up)		Apr-05	Dec-17	11	56
16. Plastics Colored HDPE (Baled, ¢/lb., picked up)		Apr-05	Dec-17	6	37.5
17. Plastics Comingled (#1-7, Baled, ¢/lb., picked up)		Nov-09	Dec-17	1	12
18. Plastics Comingled (#3-7, Baled, ¢/lb, picked up)		Sep-14	Dec-17	0	5
19. Metals White Goods (Loose, $/ton, picked up)		Apr-05	Dec-17	25	190
20. Plastics FILM - Grade B (Sorted, 800+lb Bales, ¢/lb, picked up)		Feb-16	Dec-17	4	10.5
21. Plastics PP Post Consumer (Baled, ¢/lb, picked up)		Jun-13	Dec-17	5	18.5
22. Plastics Polystyrene EPS (Baled, ¢/lb, picked up)		Nov-15	Dec-17	1	9.5